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Non Invasive Measurement and Visualizations of Blood Pressure

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Introduction

The objective of this work has been the design and implementation of a non-invasive blood pressure measurement chain composed of a pressure gauge with the wire and the Bluetooth wireless data transfers and visualization. The Envitec NIBP 2010 module was used as a measuring device. The communication interface used in this design and the implementation guideline are structured so as to provide a highly efficient data transfer and to meet all the requirements and standards relevant to both wired and wireless communications. Therefore, two types of interface routes have been employed - a serial one and a wireless Bluetooth technology link. As a part of this work, the new software, produced by MATLAB, Version 7.0.1, was present for the data processing and as a visualizing tool. The hereby presented solution constitutes one of the possible ways of short-range data transfer in telemedicine. The user interface design targets effectiveness, clarity and the ease of application. The scope of applicability of the present design and pertinent technology is quite large. Medical settings equipped with this type of technology enable several devices to be interconnected, creating a concept of telemetric medical offices characterized by mobility and flexibility [1].

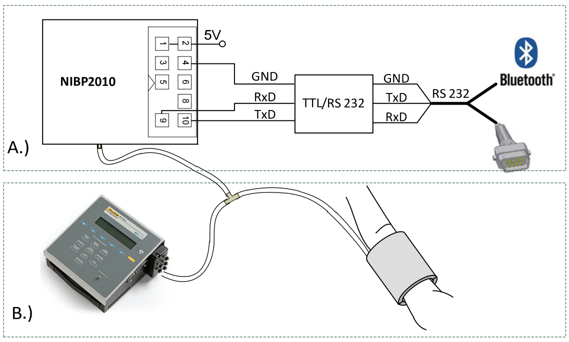

Fig. 1. A) – The measuring chain with OEM module NIBP2010 and the Bluetooth module OEMSPA 13i; B) – BP pump 2 – the non-invasive blood pressure simulator and tester

One of the main objectives was to design a functional blood pressure measurement chain. One of the basic demands, when attending this task, was to make the whole measuring device as small as possible. The second demand was safety and usability of the device in any laboratory conditions. Also, for these reasons, attention was paid to the communication interface and to the transfers of measured data. Because of these demands, we choose particular technologies and components for the measuring chain.

Embedded hardware

When realizing this task, there were priorities established for the designed chain. They related to the small size of the device and the fast and safe transfers of measured data. The used measuring device was the NIBP 2010 module by Envitec, which made measuring in the measurement chain easy, fast and effective as much as possible. An important component in this chain was also the communication interface which was designed to make data transfers from the device faster and a problem free. Fast and a problem free transferring is important because it is a device for the monitoring of a vital function when the fast knowledge of results is very important.

OEM Module NIBB2010

The normal connection with the board is done via the serial, asynchronous communication at the rate 4800 bauds. The interface lines operate on TTL voltage levels (0 and 5 volts). A bidirectional connection is necessary, because the parameters like the cycle rate and the start of measuring have to be transmitted to the module before the measuring starts.

The NIBP 2010 module is a device for the blood pressure measurement, Fig. 2. It works on the principle of oscillometric method and its outputs are the systolic, diastolic and middle pressure values as well as the pulse rate. The module is safe for both adults and children. It contains double safety network of pumps, armature and a pressure sensor. An accuracy and repeatability of measured results are very good – it was demonstrated by clinical tests. Accuracy was achieved thanks to a large number of comparative measurements.

The properties include a short measuring time, quietness, a long lifetime of pumps and armatures, which was achieved by using tried and tested components. But we could not neglect the ability of an automatic adjustment of the initial pressure dependent on the data received by previous measuring [2].

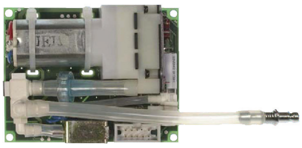

Fig. 2. The Module NIBP2010 by ENVITEC Co

Electronic solution

It is evident from the technical parameters that this device can communicate through the serial interface RS232. This technology was implemented for the communication first. The NIBP2010 power supply was 5V and its power consumption was 750 mA. It served the motor (for cuff inflation) and also other electronics. Rechargeable AA batteries with external battery charging made the power supply solution.

The problem in this work is the incompatibility of TTL with RS232. The solution uses the integrated circuit MAX232. In Fig. 4, there is the schematic diagram of MAX232.

The MAX232 serves one task – to convert the supply +12V to +5V and -12V to 0V and reverse. That all by 5V power supply. That is why there are connected capacitors in the picture. Their capacity is within the range from 1 to 10 μF. We can see their connections in Fig. 3.

These capacitors and their correct connections are very important for the converter's correct function. The next task was the power supply conversion. There are many solutions and it was difficult to tell which has been the best. One of the possibilities was to use the PC port power supply. There is voltage in some serial port pins. This voltage we did not need for communication and we could thus use it to convert the power supply.

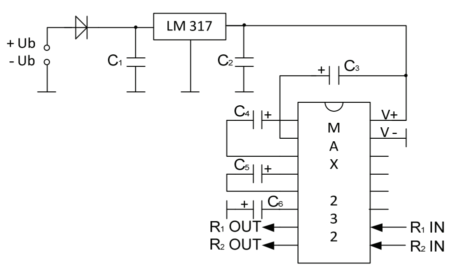

Fig. 3. The connection and power supply adjustment for the NIBP module

This solution was satisfactory, but got one big disadvantage. The power supply was dependent on the voltage from the serial PC port. And this was the problem, because we wanted to use the wireless communication. The external power supply was used as an optimal solution. The schematic diagram is in Fig. 3. The minimal power supply to this device was 8V. The final solution uses two possibilities.

The first solution uses an adapter for the external power supply. Maximal power supply is 12V. The connector for the external power supply is placed on the lateral face of the case. When we use the external power supply adapter, the batteries are automatically disconnected.

The second solution uses a battery for the power supply. Inside the device, there are six rechargeable batteries of the AA type. Their overall rated voltage is 9V. When the device works, it depends on the capacity of the batteries.

The NIBP2010 power consumption is 750 mA and, for data transmissions, we use the wireless Bluetooth communication. The power consumption of the Bluetooth module is 150 mA. Then, the total consumption is 900 mA.

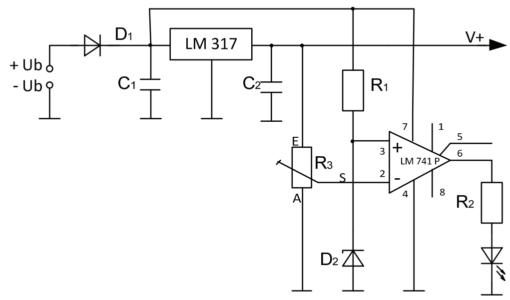

Fig. 4. The circuit signaling a voltage shortage

When testing this device, we used the battery with the capacity of 2500 mAh. So, with these batteries, we could take 330 measures. The formula for calculation of this value is

$$k = \frac{(2500/900)\cdot 3600}{30}. \quad (1)$$

This value is only for orientation, because the power consumption differs when we use the serial communication. We must consider the measuring time of 30 seconds as it is the ideal time. In other measurements, this time could be longer. The number of measures depends on the batteries' capacity. When we use batteries of a higher capacity, then the number of measurements might be higher. For battery recharging, we can use an ordinary commercial charger.

In the next Fig. 4, we can see the circuit signaling the voltage shortage. This voltage shortage is signaled by LED. When the voltage is lower than 5V, the LED will switch on. This diode is placed on the case of the device. We can change this circuit sensitivity by rotating the trimming resistor R3.

Communication technology

Among the most important parameters of this module, which also influenced its selection, are: the module supply potential within the range 3.0V – 6.0V and the max. current of 150 mA at the transmitted speed ≤ 57.6 kBit/sec.

The module contains a communication interface RS 232 and UART. The module transmitting speed is 300 Bit/sec – 921.6 kBit/sec. The other important parameters are the sufficient variability of the serial interface setting and the Bluetooth communication. The module contains an internal antenna - Mica 2.4 GHz by the GigaAnt Co.

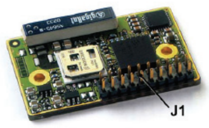

Fig. 5. The Bluetooth Module OEMSPA 13i by ConnectBlue Co

Software

A part of this work was to create a user's software which meets two basic demands. The first is the simplicity. This software is for users who can find themselves in critical situations and it is thus necessary to make the user's window simple and clear. The second demand relates to lucidity. After the end of measuring, the measured data should be immediately processed and displayed.

The MATLAB software was used for the visualization. This program is not directly intended for these applications, but it was used because it could create an effective user's interface, a possibility of fast data processing and displaying, and also for its ability to compile the final virtual device in a data format with an extension *.exe.

Fig. 6 illustrates a window of the designed software which is divided in two parts. One serves for the visualization of measured data of blood pressure and second one serves for the communication interface setting and for potential measuring characteristics.

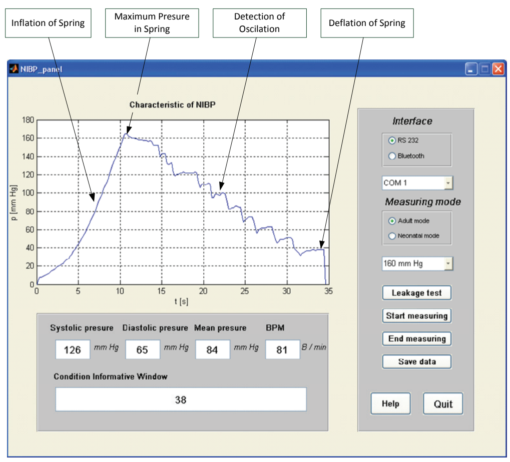

Fig. 6. The Embedded Software in NIBP2010

In editing windows, there are the measured blood pressure data displayed. It is also possible to display the pulse rate in the BPM window. The editing window "Condition Informative Window" displays an actual pressure value in an arm cuff. When there is wrong tightness or an error, the window displays "Error".

Testing experiments

For experimental measuring and accuracy measuring testing we used the commercial NIBP tester BP Pump 2 by Fluke Co. The connection of the measuring chain is in Fig. 1.

The BP Pump 2 provides dynamic blood-pressure simulations for testing adult and neonatal noninvasive blood pressure monitors, including both arm and wrist cuff types.

The analyzer features a preset mode for simulation of frequent patient conditions and the capability to program user-defined simulations. BP Pump 2 tests for leaks, measures static pressure, generates pressure, and tests overpressure valves.

BP Pump 2 comes in two models: the standard BP Pump 2L and the BP Pump 2M, which features a high-accuracy pressure transducer. BP Pump 2 also includes optional five-lead synchronized ECG simulations for the testing of monitors which monitor ECG patients [2].

Table 1. The measured data by NIBP 2010. Tester settings were 120 mmHg, diastolic 80 mmHg, mean pressure 93 mmHg, and pulse rate 75 BPM

NIBP 2010				
No. of measures	**Systolic [mmHg]**	**Diastolic [mmHg]**	**Mean [mmHg]**	**Pulse [BPM]**
1	119	83	93	85
2	120	82	94	79
3	119	83	92	81
4	120	81	93	77
5	119	82	93	78
6	119	81	93	82
7	119	81	94	77
8	119	82	93	82
9	119	81	94	77
10	119	80	94	82

The measuring chain (Fig. 1B) features the connected testing module NIBP2010. The testing values are as follows: the systolic pressure 120 mmHg, the diastolic pressure 80 mmHg, the mean pressure 93 mmHg, and the pulse rate 75 BPM. The next table presents the data from the test measuring. There were 10 measurements taken (Table 1).

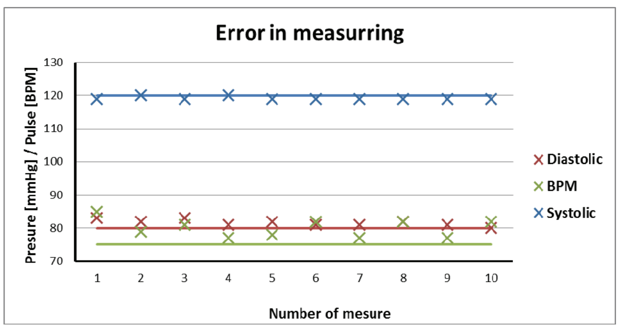

Fig. 7. Measuring deviations from the set values

These data served for finding measurement errors. The following formula was used to calculate the absolute error

$$\Delta x = \frac{\sum_i \frac{x_M}{x_R}}{i}, \tag{2}$$

where Δx is the absolute measuring error, x_M is the measured value, x_R is the real pressure value set up on the BP Pump 2 tester, and i is the number of taken measurements. For the calculation of the relative error the following formula was used

$$\delta_x = \frac{\Delta x}{x_R} \cdot 100\,[\%]. \tag{3}$$

The next picture presents measuring deviations from the values set on the tester BP Pump 2 (Fig. 7).

Conclusions

Both parts of this work – the measurement chain and the designed software, are functional and able to be used in practice, or for the extension their functions and properties. At present, the device is very flexible and mobile, but there is also an offer to upgrade it by the use of a LCD display. Then, this device could be fully mobile and could be used even without a computer. Current feeding solution is sufficient but it is also necessary to remove batteries from the device and charge them externally. An advantage would be to design a network serving the battery charging separately. The designed software is also able to be extended by addition of some functions for the signal processing from a manometer or from the data storage.

Table 2. The average relative and absolute errors

	Systolic pressure	Diastolic pressure	Mean pressure	Pulse
Δx [mmHg/BPM]	0.8	1.6	0.5	5
δx [%]	0.7	2	0.5	6.7

Despite the necessity of further improvements and extensions, the created telemetric chain application is fully functional and serviceable. Also, it fulfils the objectives of this work. The device was also successfully tested.

Connecting the used device and technologies provides a flexible and mobile device which is, thanks to its ability, suitable for the use in real life practice, when this important vital function needs monitoring.

The results of calculated errors for particular pressures are noted in Table 2.

The experimental measurements show that the measurement accuracy is satisfactory. According to the CSN standard EN 60601-2-30 of 2001, the max. mean deviation could be ±5 mmHg. It means that the measured deviations are within the standard.

Acknowledgements

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The goal of this work is design and implementation of medical non-invasive blood pressure measurement chain with distance data transmission and visualization. The main contribution is the wire and the wireless communication interface used for highly efficient data. The complete presented solution was realized and tested with the reference Fluke BP Pum 2. Results of this work can be used as modern biotelemetry equipment in medical doctor’s offices with mobile and flexible features. Ill. 7, bibl. 3, tabl. 2 (in English; abstracts in English and Lithuanian).

M. Augustynek, M. Penhaker. Neintervencinis kraujospūdžio matavimas ir atvaizdavimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 10(116). – P. 55–58.

Analizuojama bevielė duomenų perdavimo sistema, skirta neintervenciniam kraujospūdžio matavimui ir atvaizdavimui. Veikianti sistema buvo patikrinta ir išbandyta. Tokia sistema gali būti suderinama su šiuolaikinėmis biotelemetrinėmis medicinos sistemomis. Il. 7, bibl. 3, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).